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ABSTRACT

Activities and interactions of teachers and students from high school science classes of Western Australia were investigated. Fifteen teachers from two co-educational high schools (private and public) serving medium socio-economic level families in the metropolitan area of Perth participated in the study. The specific foci were: (1) the instructional and managerial roles of the teacher; (2) interactions between teachers and students; and (3) student engagement in the prescribed learning tasks. The ethnographic investigation consisted of field notes from observations of the teachers and students in approximately 200 science lessons, written self report data on student engagement, questionnaire data from teachers and interview data from teachers and students. Findings are summarized in reference to content knowledge of the teacher, activity structure, reward system, teacher expectations, and disruptive students. Implications for educational researchers, teachers, and teacher educators are presented. The study recommends that exemplary teachers be used in ethnographic studies for modeling. It is also suggested that the information from the study be used to assist teachers in self-examination of teaching practices and to assist teacher educators in evaluation of teacher preparation and continuing education programs. (ML)

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Teacher Management and Student Engagement in High School Science

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BACKGROUND

There is little doubt that student engagement in relevant learning tasks is significantly and positively related to achievement. However, despite the common sense of the engagement-achievement relationship it may prove difficult for teachers to provide all students in a class with appropriate engagement opportunities. Logistics associated with covering the curriculum, preparing for internal and external examinations, and catering for the needs of thirty or more students are likely to shape the implemented curriculum and influence student learning opportunities.

Recent reports in schooling in Western Australia (Beasly, 1984; McGaw, 1984) examined curricula and assessment practices in that state and recommended widespread changes in organization and practices in high schools. However, the research base for many of the recommended changes that related to practicing high school science was negligible. A parallel situation exists in the U.S. schools. Research on teaching and learning has focused mainly on learning outcomes and reports such as Nation at Risk (National Commission on Excellence in Education, 1983) and Project Synthesis (Harms and Yager, 1981) have advocated changes that should influence practices in high school science teaching. For example, more science has been recommended despite a lack of evidence that more science will improve science achievement. The symptoms of malaise are clear, but the underlying causes are uncertain. It is possible that changes in the intended curriculum and in the assessment system will have little effect on the implemented curriculum and that more science will have no discernable effect on achievement. Instructional and managerial practices together with teacher and student expectations and a multitude of other variables interact to drive classroom processes, influence the way that the classroom is structured, and affect opportunities for student engagement and the amount of learning that occurs. Several decades of

research has provided insights into the strengths and weaknesses of instruction but the manner in which to proceed is not clear. Further research is needed in order to understand cultural aspects of the classroom, to identify new variables that influence learning and to enhance understandings of life in classrooms.

Opportunity to learn is influenced by the curriculum, the manner in which the curriculum is implemented, and teacher expectations of student performance. In this study a variety of state-mandated curricula were implemented in two Western Australian high schools which are referred to as Private school and Public school. At grade 8 level all students studied a general science course consisting of nine topics. Students at this grade level were grouped in a manner that was heterogeneous with respect to science ability.

Eighteen additional science topics were studied in grades 9 and 10. However, in these grade levels, students were assigned to classes on the basis of their science ability. Those ability levels each received a different general science curriculum. About 40% of students in Western Australia leave school at the end of grade 10. Those who stay prepare for the Tertiary Admissions Examinations which are given at the end of grade 12. Performance on these subject specific examinations determine access to free tertiary education with only about 50% of those to write the examinations attaining university admission. Thus, there is considerable emphasis placed on examinations by both teachers and students.

Science study was elective in grades 11 and 12. Those choosing to study additional science in Private school and Public school selected one or two subjects from physics, physical science, chemistry, biology and human biology.

The range of content and curricular objectives represented in the science lessons observed in this study provided opportunities to examine differences attributable to different topics or science content areas. In addition, teacher expectancy effects

could be explored in heterogeneous classes, classes tracked according to achievement, and classes containing students who had elected to study additional science.

PURPOSE

This study was planned to investigate the activities and interactions of teachers and students in high school science classes . The specific foci were: (1) the instructional and managerial roles of the teacher, (2) interactions between teachers and students and, (3) student engagement in the prescribed learning tasks.

METHOD

Sample

Fifteen teachers from two co-educational high schools (Private school and Public school) serving medium socio-economic level families in the metropolitan area of Perth, Western Australia participated in the study. Twelve of the teachers were male and three were female. Each teacher was observed teaching several lessons to three or four different classes during the study.

Data Collection Procedures

The main component of the study was an ethnographic investigation of high school science activities. The database consisted of field notes from observation of the teachers and their students in approximately 200 science lessons, written self report data on student engagement, questionnaire data from teachers, and interview data from teachers and students.

Four trained observers visited classes during a three week period in each of two high schools. Each class was observed by at least two observers for eight to twelve lessons. Narrative records were taken during each lesson to provide a description of activities and a time log of their occurrence and duration. Data on verbal interactions were recorded along with an estimate of the cognitive level of the interaction and its substantive content.

Within the time frame of classroom observations, students completed a locus of control questionnaire and a test of logical thinking. At the conclusion of the classroom observation phase of the project all students completed a questionnaire designed to provide data to complement the observational data. Following a debriefing period, teachers completed a questionnaire in which they were asked to nominate the target students (Tobin & Gallagher, 1985) from their classes and to describe how these students were involved in their lessons. They were also asked to provide the names of students who did not contribute to classroom discussions or who were not called on to contribute.

Design

Data collection occurred in three distinct phases. In the first phase, nine teachers from Private school were observed for a period of six weeks. During the initial three weeks five grade 8 classes were observed during a general science topic on Liquids. In the second three-week interval, the study was replicated in the same school in grade 9 general science classes and in grade 11 elective studies in chemistry, physics, physical science, biology, and human biology. Nine teachers from Private school participated in the study.

The second phase of the study consisted of a replication with six volunteer teachers from Public school. In this case the schedule of observations was based on a specific teacher rather than a selected grade level. Observers tended to track a teacher for approximately a half a day. Observations were scheduled each day of the week, the schedule was changed every two weeks and phase two of the study continued for 14 weeks.

During the first two phases teachers and students were interviewed in an informal manner. The information obtained from these interviews was incorporated into the field notes and was interpreted along with the descriptive data obtained by direct observation.

The third phase of the study involved formal interviews of teachers and students. All 15 teachers and approximately 100 students were interviewed using standard protocols. The interviews were tape recorded and were transcribed at a later time.

A stratified random procedure was used to select students from each science class in Private school to assure equal samples of male and female students and a wide range of formal reasoning ability and locus of control. Students from Public school were not interviewed.

Data Analysis

At regular intervals during the data collecting phase, field notes were discussed by the observers and hypotheses consistent with the observations were formulated. Subsequent observations were used as a basis for refuting, revising, and/or accepting hypotheses. The criterion for acceptance was a decisive balance of probabilities favoring the hypotheses. Confirmation of accepted hypotheses was sought from subsequent observations. To avoid misinterpretation of the results it is stressed that the findings represent general trends for which the amount of supporting data exceeds the amount of refuting data. Exceptions to the findings were observed in the study.

RESULTS AND DISCUSSION

The results of the study are presented in five sections that deal with content knowledge of the teacher, group structure, reward system, teacher expectations and disruptive students. A final section contrasts the managerial styles of three teachers.

Content Knowledge of the Teacher

The 15 science teachers ranged in their teaching experience from 1 year to more than 25 years of teaching. The median teaching experience was approxi-

mately 7 years. With two exceptions the teachers were well qualified to teach high school science and taught science topics for which they had relevant expertise. One female teacher was a substitute with a degree in English and a male teacher had a degree in Social Science. These two teachers each taught one grade 8 science class.

The general science course taught in grades 8 to 10 presented a challenge to all teachers in the sense that 27 topics, ranging across the scientific disciplines were to be taught and the timetable in each school was organized such that teachers taught a class for the entire year. As a consequence, teachers frequently were engaged in teaching topics which were outside their disciplinary expertise.

Three of the teachers observed were required to teach grade 11 classes in which their tertiary background was limited. In Private school, a biology teacher was also teaching a grade 11 human biology class; and in Public school a chemistry teacher was teaching grade 11 physics and a biology teacher was teaching grade 11 chemistry. These unusual situations enabled comparisons to be made between the teaching style used when teaching in and out of field. Each of the examples is discussed below.

Example 1. Teachers in the study taught biology and human biology in much the same way. However, the teacher who was relatively unqualified in human biology relied to a considerable extent on the textbook and mimeographed notes as data sources in human biology classes. During whole class interactions the teacher used his lesson notes and did not elaborate on student responses to relatively convergent teacher questions. In contrast, the same teacher taught biology in a more flexible manner whereby he often introduced new content by elaborating on

student responses to higher cognitive level questions and by inviting student questions. The teacher appeared to be more confident in the biology class and taught without reference to his lesson notes. In the interview the teacher indicated that he did not like teaching human biology and was reliant on lesson notes provided by the main human biology teacher who had planned the program and prepared the mimeographed materials.

Example 2. The chemistry teacher observed that he was more relaxed when he was teaching in his field than when he was teaching out of field. He stated that the comparison between teaching physics and chemistry provided a good example of this difference. Physics tended to be more note oriented and he did not feel confident unless he had his textbook in front of him, notes on hand, and a set of problems for students to attempt. He did not like to get sidetracked too much in physics because he might be unable to deal with questions that arose. In contrast he was able to teach chemistry in a relaxed manner without reference to notes or the text. His chemistry teaching style was more discussion oriented and he was prepared to allow discussion to drift away from the central part of the lesson.

Example 3. A teacher with strong qualifications in biological sciences taught in a confident and elaborative manner in biology and human biology. He tended to use his knowledge to advantage by encouraging student questions and building on the responses he received. Target students were evident in his biology and human biology classes and their role appeared to be associated with content coverage and development. In his grade 11 chemistry class the target students appeared to have a different role. In this class they supplied facts in response to questions and appeared to be confirming that they had understood prior instruction. The teacher tended to direct questions to the whole class rather than to individuals. This style of questioning encouraged students to respond in chorus fasion, and of course,

target students were favored. Little time was provided for pupils to generate ideas and in many cases the teacher answered the questions with the aid of the chalkboard. This style of interacting with the whole class was characteristically different from the style of interaction in the human biology class. There was also a higher level of student inattention in chemistry than in human biology. The teacher seemed to be less concerned with supervising the class as a whole and encouraging student participation than with keeping on top of the content. In part, the observed differences probably reflect the teacher's greater familiarity with the human biology syllabus and his greater subject area competence in that field. During the interview with the teacher he stated that he had not taught chemistry for a number of years and was not as familiar with some of the content in the organic chemistry component of the chemistry course as he would have liked to be.

At one stage in a chemistry lesson the teacher asked a question about the functional groups of given substances for which chemical formulae were provided. The students in the class were unable to respond to the question. After a time a male student asked for clarificaiton. The teacher provided the answer to the problem and the students copied the answer into their notes. However, after raising the question, the student had little opportunity to raise further concerns. This was in contrast to the typical teacher behavior in human biology lessons where elaboration was provided and questions were invited on almost any content area. In the chemistry lessons the teacher seemed eager to cover the content rather than ensure that all students had developed the concepts necessary to attain the lesson objectives.

Discussion. The above examples indicate that teachers do tend to behave differently when they are teaching outside of the content expertise. In each case

the teacher's relative lack of knowledge affected content sequencing and the quality of the interactions with students. There also was evidence that the need to focus intently on content recall and sequencing made it difficult for one teacher to concommitantly attend to student misbehavior.

Activity Structures

In the two high schools studied, all science classes, grades 8-12, met six periods per week with one double period scheduled continguously each week for laboratory work. Not all laboratory periods were used for laboratory work; frequently, regular class activities were continued throughout the double laboratory period. In higher grades, teachers tended to adhere more closely to the plan of two-thirds of instructional time devoted to classwork and one-third to laboratory work.

In the classes observed, teachers generally placed a high degree of emphasis on the completion of tasks and activities. It appeared that most teachers believed that (a) task completion and learning were identical, (b) it was their job to "cover" the material in the text and laboratory guide (which were congruent with the state-mandated syllabus for each course), and (c) if they completed that task, their responsibility to the students regarding the specified content was fulfilled. Thus, they tended to work in a way that resulted in the work being completed. Whether or not learning occurred was perceived as the students' responsibility.

In the classes observed, four major types of activities were noted: (1) whole class interactive, (2) whole class passive, (3) individual seat work, and (4) small group work. As would be expected the role and behavior of teachers and students in each of these differed. Each will be discussed in turn. Teachers' activities and student engagement will be described for each.

(1) Whole class interactions between students and the teacher constituted the predominant classroom activity. Activities in the category included teachers presenting content in a lecture mode, but with frequent questions being asked of students to increase their engagement. It also included student initiated questions, discussion as part of a demonstration, review of answers prepared by students in response to homework assignments, discussion of science related incidents in the news or from students' experiences, review in preparation for tests, and other familiar instances where the teacher is the center of an on-going dialog with individual students regarding the content of instruction, while other students listen.

In this setting, teachers were able to engage students regarding instructional content while retaining a high level of control over pacing of the lesson. Although some part of the whole class interactive mode was carried by questions initiated by students, the predominant form of dialog derived from questions which teachers asked.

It is here where the role of target students in classroom management was most obvious. Target students not only were asked more questions, but the cognitive level of the questions asked of them was higher than for questions asked of other students. Typically, teachers asked about 40 questions in a class period with about 25 questions (more than 60%) asked of 5-7 students. Also, it was common that 3-5 other students would receive essentially no questions over several days. The remainder of the students would be asked an average of one question during the class period. Higher order questions (requiring comprehension, application, analyses, or synthesis) were asked almost exclusively of target students. Target students were also asked questions which served as the basis for instructional transitions from one concept or topic to the next. Non-target students typically were asked recall questions and very rarely were they asked higher order questions or transition questions.

Test data showed that the target students tended to score higher than others in the class on formal reasoning and self-efficacy scales (Tobin & Galiagher, 1985). Observational data showed that target students (a) were asked more questions by teachers, (b) volunteered more answers, and (c) initiated more questions of teachers which were revelant to the topic being discussed. Moreover, when teachers were asked to list target students in their classes after the observational period, as well as students whom they rarely called upon, observers' lists and teachers' lists showed nearly complete congruence. Also, it was noted that target students tend to sit in key places in the classroom where visual or vocal contact is easy. They either sat quite close to the position in the room where the teacher tended to spend the larger share of instructional time such as near the overhead projector or near the demonstration desk or they were seated in a place where eye contact between teacher and student was easy. In this regard, students may enhance or detract from their status as a target student on the basis of the seat they elect. Physical appearance also may play a role. During our observations, it was noted that target students were well-dressed, neat, and self-assured.

In discussing the pattern of questioning with teachers, reactions were varied. Some teachers were apologetic about the inequities in their questioning behavior and indicated a desire to engage more students because it would aid their learning. However, a clear majority of teachers defended their engagement strategies stating that reliance on target students was essential in order to make smooth, logically sound transitions from one concept to the next during a lesson. They indicated that the halting pace and mis-information that would be introduced by the less able students would detract from the effectiveness of the teaching environment.

Teachers also were aware that some students in their classes received very little attention during whole class interations. Most justified this with a mixture of compassion and disregard for those students who rarely were asked questions. When queried about reasons for not asking any questions of three students in his biology class over several days, one teacher stated, "I'm embarrassed to keep asking them questions because they never are able to answer. It would be a joke to ask them a question which they could answer. Other students know what I am up to. So would they. Besides, those students have given up. They are just putting in their time until the end of the term. They won't be able to pass their exams. They know it and so do I."

The data presented in the previous paragraphs provide important insights about teachers' management of the pace and character of instruction in whole class interaction which occupies over 50% of instructional time. First, in classes averaging 24 students, only 5-7 students in each appeared to be engaged overtly much or all of the time. These are the target students who respond to over 60% of the questions asked by teachers. These students tended to volunteer more answers and they are asked more questions. It was not clear if the remaining students were actively engaged mentally, or if their engagement was more passive or covert, or if they were not engaged in instruction, or if they "tuned in and tuned out" alternately. Experience and observational data suggested that some students fell into each of these four categories.

Questions to non-target students may be seen as attempts by teachers to enhance the "mental engagement" of students or to increase the amount of time students are "tuned in" and decrease the amount of time they are "tuned out." Leaving 3-5 students with virtually no questions suggests recognition, on the part of teachers, that these students are not engaged significantly in instruction.

Second, pacing instruction on the responses of target students, who tended to be the best students in the class minimized diversions and allowed teachers to progress through the instructional content rapidly. Moreover, it was rewarding to teachers because they received more correct answers than they would obtain from less able students.

Third, pacing instruction on the responses of target students served the "sorting function" of education. Since only 25% of those entering grade 8 will be able to enroll in tertiary education, and of those less than half will be able to enroll in programs which prepare future scientists, engineers, and physicians, secondary science can be viewed as a vehicle for identifying the top 10-15% of the students as candidates for tertiary science education. With the instructional pace determined by the most able students in the class, two important occurrences follow: (1) More content was "covered" which contributed to the preparation of future scientific talent, and (2) the more able students were nurtured with higher order questions, more personal attention in class, and often the formation of personal friendships and intellectual bonds between them and their science teachers. It is highly probable that this special treatment enriched the self-esteem of target students and enhanced their scientific knowledge and their logical reasoning abilities. Moreover, for the most able students, this special treatment appears to have occurred year-after-year throughout secondary school.

For less able students, the effects may have been negative and even devastating. Less able students saw the few target students receiving attention, positive feedback, and help with learning the subject matter while they were given little attention, negative or no feedback, and litle or no help. It would appear that this would result in adverse effects on self-esteem, motivation, and understanding of subject matter.

Fourth, these observations about pacing of instruction were counter to existing research data and our beliefs about instruction. It is widely assumed that teachers tend to teach toward the middle of the class. The general belief is that teaching toward the middle is a way of benefiting the majority of students while leaving room for work with both advanced and less able ones. Dahllgren and Lundberg (Clark & Peterson, 1984) have studied pacing of instruction in elementary schools and found that teachers generally determine the pace of instruction according to the responses of a "steering group" composed of students in the 10th to the 25th percentile. Thus their findings are quite different from our observations since, in science classes observed in this study, it was the most able students who served as the "steering group." Subsequent observations in secondary science classes in U.S. schools provide further evidence of able target students as referents of pacing (Gallagher, 1985).

(2) Whole class instruction with students as passive (non-interactive) recipients of information was used when teachers wished to introduce a new topic, summarize a topic before going on to another one, or when they wished to increase the pace of instruction, often due to spending more time than planned on a previous topic. Films, videotapes, and filmstrip presentations tended to be carried out in a non-interactive mode. For most teachers, the amount of time using this mode of instruction was relatively small (less than 20% of total instructional time) if audio-visual based instruction is excluded. The main reason for this is well known to classroom teachers: Students tire of it quickly and behavior management and control must be strengthened. With films however, students generally watched quietly and appeared to be attentive.

(3) Individual seat work was intended to be non-interactive and it served some important functions in classroom management. One of the most frequently

used behavior management techniques to redirect students back on task during whole class activities was for the teacher to require students to copy a definition, an important conclusion, or a major idea in their notebooks. Teachers would dictate the statements to the students or write them on the chalkboard and students would copy, usually without speaking. Somehow, this activity was perceived by students as having top importance, and when teachers said copy in your notebooks, students became engaged in the task quickly. Teachers often relied on this pattern of behavior to reduce noise and to ensure that nearly all students were on task. Copying tasks tended to be short, perhaps only a sentence or two, and they occurred usually one to three times per period.

Individual seatwork also took on other forms including completion of work-sheets, exercises from the textbook, and outlining (or note taking) as students read silently in the text. These activities tended to be of low cognitive demand and they often occurred near the end of the class period. Students often helped each other with their tasks and/or they chatted quietly (but freely) about matters unrelated to science as they engaged, somewhat half-heartedly, in seatwork.

(4) Small group work consisted mainly of students working in teams collecting data in the laboratory. With one-third of instructional time (2 of 6 periods per week) scheduled for laboratory work, student engagement and teachers' laboratory management strategies were of great interest.

It was noted that teachers varied in their use of scheduled laboratory time. Some teachers adhered to the schedule strictly, but many used some scheduled laboratory time for non-laboratory instructional activities such as reviewing for tests, introducing topics, showing films, etc. Typically, laboratory activities were therefore reduced to about one-sixth of the instructional time; actual laboratory work was approximately half that which was scheduled in the two schools studied.

When students were collecting data in a laboratory session, it was apparent that a system of rules operated which was different from that in effect during other times. The pace of activity invariably was set by the students and engagement was intermittent with short periods of attentive work on-task being interspersed between periods of off-task behavior. Chatter with other members of the team, about topics bearing no relation to the laboratory activity, was common. And just when the observers were certain that no further productive activity would occur as students were lost in conversation about last evening's TV show or a recent sporting event or a musical group, students would switch back to the laboratory work and accomplish something significant. Also, students would periodically call out to one another and hold brief conversations in loud voices across the room. In addition, students moved about the room during data collection activities. Part of the reason for movement was to acquire equipment and materials needed for the activity. In some cases, students were required to move from station to station in data collection. A large portion of the movement, however, was simply social. Students would leave their station to talk with others about topics unrelated to the task at hand. During all of this, teachers usually worked to dispense equipment and supplies and helped small groups with the techniques and details of the laboratory activity.

What was most interesting about laboratory work was that the "rules of behavior" were not unique to any one class or building and the teachers accepted the high level of movement, talking, and off-task behavior, which were accepted for non-laboratory settings. Teachers held different expectations for student behavior in the laboratory and in the regular classroom context, even though these usually were the same room. In whole class and individual activities, students were required to be quiet, stay on task, and not leave their seats. During laboratory

activities, the converse generally was true. Students were permitted to talk, often quite loudly. Off-task behavior, including movement around the room, was common and only the most flagrant demonstrations of off-task behavior were reprimanded.

Another contrast between laboratory work and regular class work concerned pacing of activities. In whole class and individual activities, the teachers determined the pace of instruction usually from cues obtained from more able "target students." In laboratory work, students tended to be the determiners of the pace of the activity. Students appeared to know that the entire period was set aside for laboratory activities and they worked at a pace that allowed the work to consume the allocated time. As a consequence, laboratory sessions were characterized by a leisurely atmosphere with students off-task for extended periods of time.

The actions of teachers during laboratory activities also were of interest. For U.S. teachers, it may come as a surprise that equipment and materials management is the responsibility of laboratory technicians in Western Australian high schools. To prepare for a laboratory activity, teachers provided the technician with a list of needed materials and equipment and it was available on a cart ready for use at the time specified. In spite of this, teachers spent some portion of laboratory time dispensing equipment and searching for items which were overlooked as they drew up their list of needed supplies. But most of the time in laboratories, teachers appeared to be helping students with the procedural aspects of the laboratory work such as how to assemble apparatus correctly, how to observe and record data properly, and how to dismantle and return apparatus. Teachers often repeated these procedural instructions for one group of 3 or 4 students, then another, and another. Teachers rarely asked students if they

understood what they were doing, why they were doing it, or what the results would show. Over all, teachers seemed to be quite concerned about procedures but showed little concern for the cognitive outcomes associated with laboratory work. Moreover, given the high level of distraction in the laboratory, it is not surprising that little attention was given to the purposes and meanings of the data being acquired.

In this sense, the small group work in the laboratory bore a significant relation to the other activities of the whole class and individuals: It, too, was a task to be done! Typically, laboratory activities were based on a recipe approach with actions to be completed and data to be acquired and written in appropriate spaces on a work sheet, thus reducing the cognitive demand of the laboratory work to a minimal level. Students satisfied a set of requirements established by the teachers, but the requirements were of such low demand that meaningful learning could hardly occur. Moreover, the social ambiance of the laboratory precluded reflective thought and concentration. As a consequence, students had a good time with their peers during laboratories but the authors question if much relating to science was learned by the students.

Several other points can be made regarding small group work in laboratory settings in secondary school science classes observed:

1. Boys tended to play a dominant role in laboratory activities. When they worked on coed teams, girls often watched or recorded data.

2. Both boys and girls tended to spend time off the laboratory task in social interactions with peers, but boys also spent time off task fooling with and exploring equipment.

3. For some misbehaving students, participation in laboratory activities was used by teachers as a priviledge that sometimes was denied, but reports on experiments were still required.

4. Laboratory reports appeared to receive greater emphasis than the processes of acquiring and interpreting data. In most cases, teachers dictated conclusions or wrote them on the chalkboard for students to copy.

5. The form of laboratory reports seemed to receive more attention than their content. One teacher expressed this attitude succinctly when asked by a student about the Conclusions to be drawn from laboratory activity by saying, "You know that in my class, you leave four lines for Conclusions."

Based on observations of dozens of laboratory sessions conducted by several teachers, it was difficult to infer the purposes of laboratory work from its implementation. It appeared to be another part of the "work to be done." Nurturance of the skills of inquiry, the values of science, or even understanding of scientific principles did not appear to be part of the teachers' intentions nor did they appear to derive from the context of laboratory activities.

Like most activities observed with the whole class and individuals, the small group activity appeared to suffer from a lack of context. Quite generally, science instruction tends to occur without beginning or ending--it just seems to run on! Laboratory activities rarely were preceeded by a "pre-lab" discussion which gave students a clear sense of (1) the purposes of the activity, (2) the procedures to be followed, and (3) the connections between purposes and procedures. Typically, students were given a worksheet and some general instructions about the activity and the location of the materials needed. They rarely were given an opportunity to acquire and think reflectively about the 3 points raised in the preceding sentence. As a consequence, students began work without a clear sense of what they were doing or why they were doing it. This was confounded by the fact that students often were asked to carry out four or five different short experiments in a laboratory period by moving from one station to the next.

With students not having a clear sense of purposes and procedures, or their interconnections, teachers were then forced to answer the same questions repeatedly as they moved from one student group to another. Moreover, since the connections between procedures and purposes in laboratory activities often are

subtle and usually require reflective (formal operational) thought, which many students find difficult, their questions to teachers tended to be more concrete, pragmatic, procedural questions. Thus it appeared that the management strategy employed by most teachers of providing only superficial pre-laboratory instruction led to a situation which inadvertently reduced the cognitive demand of laboratory sessions.

In post-laboratory activities, teachers were unable to draw meaningful conclusions from students because the experience in laboratory session did not provide them with meaningful information. Students went through the form of gathering and recording data but they did not comprehend the meaning of their actions or the data which they acquired and recorded. Therefore, teachers provided students with "ready made" conclusions to record in their laboratory reports as a way of bringing closure to a sequence of activities that consumed one-sixth to one-third of instructional time in each week. Given the set of circumstances, it is understandable why teachers infringe on laboratory time with other activities.

Overall, laboratory activities did not appear to contribute significantly to students' understanding of the content and processes of science. They seemed, instead, to be a desirable diversion from the main point of instruction. Teachers treated laboratory activities as a required part of the work to be completed, but with one important difference: Laboratory activities were exempted from the time pressure associated with whole-class or individual activities. Although teachers exhibited a strong tendency to "press on" during other class activities, this was not the case in laboratory sessions. As a consequence, laboratory work can be viewed as a rather "expensive" component of the science program, consuming a large propotion of instructional time in activities where benefits are difficult to infer.

Reward System

Teachers tended to use activity settings that enabled the academic work to be completed so that students could take the test or exam at the scheduled time. At all grade levels teachers frequently attempted to motivate students by referring to the test or the exam. Work identified as being likely to be tested assumed a higher status than work that was not so identified. The identification of content that needed to be learned for a test or an exam was usually associated with written handouts, note taking or textbook summaries. Other work tended to assume importance only if it was assessed. Consequently, the laboratory write up and homework had a high status in most of the observed classrooms because these products of the activities were assessed.

Most teachers partitioned the academic work into lesson sized chunks and moved through a program in a systematic linear fashion. Several consequences of the teachers' endeavors to complete the academic work were frequently observed. The first two of these have already been discussed in detail. The use of a whole class interactive setting for so much of the allocated time was probably a consequence of the teacher needing to retain control of the pacing and sequencing of activities. Similarly, the use of target students enabled the teacher to involve students, but to maintain the momentum of the lesson by selecting those students who could be relied upon to produce appropriate responses.

Note taking was common in most grade 8 to 10 classes and in very many grade 11 classes as well. This activity appeared to take an inordinate amount of time because the pace was usually determined by the last person to finish. Students who were off task during the activity often prolonged the time the teachers allocated resulting in a situation where the early finishers were off task as they waited for an additional assignment. A frequent problem observed in

conjunction with note taking activities was that teachers expected students to engage simultaneously in more than one activity. For example, as students copied notes it was quite common for teachers to clarify or elaborate on the points contained in the notes. The majority of students tended to continue copying the notes when these discussions were taking place. In these circumstances it was difficult to see how students could benefit from the note taking activity or the teacher explanation.

On final example of teachers scheduling activities in order to complete the academic work occurred with lower level grade 9 and 10 classes. Teachers frequently complained to observers and to colleagues about the difficulty of teaching science to these students. However, there were signs that teachers did not always rise to the challenge. For example, in one grade 9 lower ability class students were allocated two double periods to complete a crossword puzzle on insects that required familiarity with words not encountered in the course. A further two double periods were scheduled to watch films on insects and arthropods. In both instances the teacher stated that the film had not been previewed before screening. Each of the films contained content that was at a cognitive level beyond most of the students in the class and discussion did not precede or follow showing of the films. The paradox in this situation was that the teacher believed that lower ability students were unable to retain science knowledge for any period of time. Through the use of whole class passive and interactive modes, and individualized activities the teacher completed the topic on insects in less than two thirds of the time taken for an intermediate class taught by the same teacher. Rather than involving the less able group in revision activities or "hands on" laboratory investigations the teacher opted for activities that were easy to manage. The academic work had been completed and therefore the teacher's responsibility was seen to be to fill the allocated time.

In grades 8 to 10 teachers tended to cover content areas in a general manner and usually avoided specific detail. Information tended to be presented without discussion. There was no probing of the logic underlying the presented content. For example, in a discussion of pasteurization, one teacher explained that elevated temperature killed the germs contained in milk and other germs are excluded by the carton; and that pasteurized milk needs to be refrigerated. There was no explanation or discussion of why the milk needed to be refrigerated.

The cognitive level of the academic work was reduced by allowing students to copy information relevant to questions and problems from the textbook. In the observed lessons there were few examples of the teacher assisting students to understand scientific principles or to develop generalizations from known content. The lessons tended to focus on explaining the meaning of content contained in the syllabus with the aim of identifying the content areas that needed to be learned for a test or an examination.

There needed to be much more time devoted to the conceptual aspects of the curriculum for students to have benefited from the program and learned about science. There was insufficient discussion about the questions that were raised and there were too few opportunities for students to raise their own questions. When students in a higher ability tenth grade class were allowed to ask their own questions about Genetics, the science class really seemed to spring into life. This did not occur in a lower ability tenth grade class taught by the same teacher or to an appreciable extent in other classes. It was not that students were prevented from asking questions, they were certainly given opportunities. After the questions had been answered the lesson continued and there was not time to reflect, to argue, to assimilate information from diverse sources or perhaps to learn. In short, the pace of content coverage appeared to be too fast.

The cognitive level of the interactions was very high in grade 11 biology classes. This was due mainly to the emphasis in discussion on the questions from the book. The majority of the observed biology lessons were devoted to discussion of questions that the students had attempted at home. The lessons were usually not used to introduce new content. Fortunately the book posed many questions that were worthy of discussion and the questions and subsequent discussions reflected this worth. All teachers elaborated around responses given by students.

In all of the grade 11 subject areas, teachers provided students with type examples, algorithms and rules of thumb to reduce the cognitive level of the work and to enable students to cope with the work with lower cognitive level skills. For example, students were given countless examples of the same type of problem to enable them to recognise that type if it occurred in an exam. The general approach for solving each type of problem was made routine as a result of working a large number of similar problems. As a consequence, students were able to obtain the correct answer without necessarily understanding the principles of physics or chemistry that were involved in the problem.

A similar phenomenon also was evident in grade 8 to 10 science classes. Student interviews indicated that many students were able to solve complex problems by applying a formula that had been rote learned in a systematic manner. Discussion of the problem indicated that students had scant knowledge of the scientific principles but had learned an approach to obtain the correct answer.

Scientific jargon was used frequently throughout the lessons in all classes. The purpose of this jargon was usually not clear. On several occasions, observers noted that terms that are rarely used outside of a classroom were used once, were never really explained, and were not used again. This made learning most difficult and would certainly present a learning block to many students in the classes

observed in this study. For example, the use of terms such as centriole and metaphase appeared to contribute little to the development of a grade 10 genetics lesson, but it did make it difficult to glean meaning from the material presented in a lecture mode or for students to benefit from the clarifying discussions.

In low ability classes there were problems with the relative complexity of the content to be learned and the terminology used to explain the content. For example, terms such as rarefactions and compressions were difficult for students to understand and a diagram on the wave nature of sound was also complex. In many cases the curriculum did not appear to be relevant to the needs of low ability students who appeared to struggle to recall complex terminology and facts. Crossword puzzles were used in many observed lessons. However, the terms incorporated into puzzles were often obscure. For example, students in the low ability classes observed in this study were unlikely to benefit from locating terms such as isoptera and chericerae in their books and inserting them in the relevant places in a crossword puzzle.

Teacher Expectancies

The existence of target students was one clear example of teacher expectations influencing the way that students engaged and received feedback. Teacher interviews and observations revealed a number of trends that could also be attributed to teacher expectancies.

The results of the study suggest that teacher expectancies affected the implemented curriculum. Results presented earlier in the paper illustrate how teachers tended to involve target students and males in whole class interactions to a greater extent than non-target students and females. Teachers expectations also appeared to influence the science curriculum for high and low ability classes.

One teacher explained that school constraints required low ability classes to study a science curriculum that was often inappropriate to their needs. Consequently, he was not certain that he had taught the lower ability students much science content and he said that he had concentrated more on attitudes. He believed that these students did not have the ability to learn a lot of science facts, however, they were good at taking down notes and they liked note taking activities because they were not challenged to think and knew that they wouldn't make a lot of mistakes.

In a comparison of high and low ability grade nine classes another teacher said that he tended to spend more time providing lower ability students with information in the hope of "getting some back." The activities consisted of shorter, simpler exercises which were watered down considerably in comparison to those presented in higher ability classes. He stated that he gave lower level students a lot more work designed to keep the students busy. He cited crossword puzzles and word sleuths as examples of such activities.

The observations suggested that the low ability class received a bare bones type of course that did not deviate to any great extent from the material in the text book. There were few examples of interactions that demonstrated that students were enjoying the content or that they perceived it to have relevance to the world in which they lived. Newsworthy topics discussed in other classes, such as heart transplants and sperm banks, were not discussed to the same extent in lower ability classes.

Disruptive Behavior

In our observations, it was noted that students can disrupt instruction in ways that are both socially acceptable and socially unacceptable. The following examples serve to illustrate the point. In a twelfth grade biology class in which

high achieving students were preparing for the university entrance examinations, students were presented with a complex task of relating observations of the geographic distribution of different subspecies of an eastern Australian bird. Smaller birds were found in the north and inland whereas larger birds were found in the south. The basic principles involved were (a) body size and surface to mass ratio are inversely proportional, (b) surface to mass ratio and rate of heat loss are directly proportional, (c) greater ambient temperatures require greater heat loss, and (d) ambient temperatures are inversely related to latitude and distance from the ocean. To understand and to explain the observations regarding these subspecies required logical coordination of these four principles with the data which showed that body size of the southern birds was larger than the northern birds of the same species. The students had a hard time managing all the pieces of information needed to comprehend and explain the observations. As a result, several students talked heatedly with their neighbors, confessing their inability to explain the observation. There was substantial off-task behavior, laughter, and other actions which could be interpreted as avoidance of a difficult task.

In a tenth grade science class, low achieving students participated in an outdoor demonstration in which a student clanged two trash can covers together by swinging his arms from full lateral extension to full medial-dorsal extension in a one second cycle while standing a distance of 170 meters from observers. The effect was that observers heard the sound of the impact of the covers as they saw the demonstrator reach full lateral extension. After the demonstration, the teacher attempted to assist the students with interpretation of the observations. The principles involved were (a) the visual image traveled the 170 meters in a time frame too small to sense (i.e., instantaneously), (b) the time between full medial extension and full lateral extension equalled the time required for the sound to

travel 170 meters, (3) that time equalled 0.5 seconds, (d) if sound traveled 170 meters in ½ second, it would travel 340 meters in 1 second. Thus, the demonstration was to show that sound traveled 340 meters/second as indicated in the textbook. Understanding and interpreting the observations required coordination of the sensory data and these four principles. As with the biology students, these students had great difficulty in grasping and managing all of the pieces of information needed to comprehend and explain what had been observed. These students, however, responded differently. They were highly inattentive. They called out to others in the room; there was punching, throwing of pencils and other objects, and other actions which led the teacher to write the conclusion on the chalkboard and demand students to write it in their notebooks. In both these cases, students were presented with tasks of high cognitive demand which they were not immediately able to solve. Both groups of students dealt with it in a disruptive manner. The biology students' disruptions were within acceptable bounds whereas the tenth grade students' disruptions were not socially acceptable. Within a very short time, the biology teacher was able to redirect students and resume analyses of the problem, whereas, the tenth grade teacher had to change the task to reestablish order.

A possible explanation of the difference between the two groups lies in their perception of their own ability to succeed at the task. The biology students were high achievers and, after some task avoidance, returned to the task. Because of their previous experiences, their confidence in their ability to comprehend the problem confronting them was reestablished quickly, and as a result, went back to work after a minor disruption. The tenth grade students, however, had a lower self-concept. They had little history of success with complex reasoning tasks and acted to preclude further embarrassment with failure on such tasks. Therefore,

they engaged in behavior that made it impossible for the teacher to refocus their attention.

It was interesting to note that less than 10 minutes later, the tenth grade teacher directed the students to watch a demonstration. It was an intriguing demonstration and every student in class was silent, watching and listening with rapt attention. It was hard for the observer to believe the degree of change in students from one task to another. However, the cognitive demand of these two tasks asked of the tenth grade students were substantially different and they responded attentively to the one (observation) at which there was little risk of failure but disrupted the interpretive task at which they perceived inevitable failure.

Styles of Effective Management

Three effective management styles were displayed by teachers during the study. Each style was effective because a classroom environment which was conducive to learning was maintained in each of the classes taught by the teachers. Each style is described below.

Style 1: The strict disciplinarian. Students in all grade levels entered the science classroom in an orderly manner with their science notebooks and textbooks ready for use. The teacher supervised the movement into the classroom and commenced work as soon as possible in a businesslike manner. The teacher had clear expectations that students would be on time for class, would enter the room in an orderly manner and would commence work immediately. Students who did not comply were reminded of the expected standards of behavior. During an interview with the teacher he stated that it was important to be consistent in the way that rules were applied and enforced. The teacher explained that many of his colleagues had difficulty in maintaining discipline because they often overlooked

misbehavior from some students. This, he said, created an atmosphere in which other students felt that they too could transgress without being disciplined.

The science content was presented to all classes in much the same way with an emphasis on whole class interactions and demonstrations. In this way the teacher was able to control the pacing of the lessons and the amount of noise in the room. The teacher directed questions to the whole class and encouraged students to raise their hands and attempt to answer. Students were continually reminded not to call out answers to teacher questions without first being asked to respond.

Style 2: The supportive helper. The second style differed from the first in the way that the teacher interacted with the students in each class. This teacher taught in a relatively structured manner but he had a warm approach to students, frequently used humor, and endeavored to personalize his science lessons. Students entered the classroom in a relaxed manner and often chatted among themselves and with the teacher about topics that were unrelated to their schoolwork.

At all grade levels this teacher used homework as a means of covering content in the text. Frequently, classtime was devoted to a discussion of questions answered for homework. This enabled the teacher to be diagnostic during science lessons and to alter the pace of content coverage so that students could have more time to build understanding of concepts and principles which comprised the content of instruction.

In both styles 1 and 2, however, teachers' choices on pacing were based on the responses of more able students in classes. Both teachers tended to ask more questions of target students and slower students tended to be left with less than complete comprehension of principles as the class moved onward to the next topic.

Style 3: The self-paced advocate. The third style differed from the first two in that the teacher advocated the use of self paced learning whenever possible.

Students tended to cover the content of grade 11 and 12 physics by progressing through problems at their own rate and checking their solutions with those contained in an answer file at the front of the room. The content was covered by augmenting material from the text with mimeographed notes.

Teacher-centered tutorial sessions were scheduled for students having difficulty with specific problems and content areas and for the more difficult parts of the course.

This teacher also maintained a consistent set of expectations. Students were permitted to work at their own rate during class time, but were expected to complete all of the required work by a specified time. The approach enabled the teacher to use class time for diagnosing student weaknesses and for assisting those in need of help. Thus, this teaching style gave more attention to the learning needs of less able students while maintaining approximately the same pace of content coverage as evidenced in other styles.

IMPLICATIONS

This research has implications for educational researchers, teachers and teacher educators. Educational researchers need to give attention to descriptive naturalistic studies of teaching practice because (a) it is important to understand science teaching as it is being practiced by experienced, well-trained teachers and (b) replications of detailed studies of practice are essential to address questions of generalizability of findings. Further, given the data of the study as a basis for formulation of questionnaires and generation of hypotheses, additional studies, using alternative methods, may be designed and conducted.

Researchers might give consideration to the selection of teachers for studies of this type. Use of volunteers or random selection of teachers for detailed study provides information about conditions of practice but it may not show exemplary

teaching behavior. Ethnographic studies of teachers nominated for their exemplary teaching technique could provide a range of teaching styles to be used by teacher educators and teachers as models of effective practice.

Teachers can use results of the study to engage in self-examination regarding their own individual practices. For example, teachers can ask questions of themselves such as (a) In what ways is the pace of instruction determined in my class? (b) Do I use target students to determine the pace? (c) Who are my target students? (d) How did they become target students? (e) Are there students whom I ignore or only rarely call upon? (f) What kinds of questions do I ask of these students? (g) How do I use seat work? (h) Is small group activity used only for laboratory work? (i) Do I prepare students adequately for laboratory work so that they know the purposes of the lab activity, the procedures to be used, and the connections between them? (j) What kinds of questions do students ask of me in lab? (k) What do their questions tell me about their preparation for the activity? (l) Are students able to draw meaningful conclusions from laboratory work without my help? (m) How do I bring closure to the laboratory activities? (n) What is my role in laboratory activities? (o) What purposes do laboratory activities serve in my science program? (p) To what degree am I governed by the need to "get the work done" without worrying about students' learning?

Teacher educators can use the results of this work to examine their programs for preparation and continuing education of teachers. Each of the questions presented in the previous paragraph can be used to help prospective and practicing teachers become more aware of their own actions and how they bear on students' learning. Moreover, the research helps to illuminate specific practical issues of student engagement and instructional management which are important parts of practice and about which teacher educators and their students need to know more.

Finally, the research underscores the complexity and difficulty of the task assigned to secondary science teachers. This research should help to call attention to the need for more effective programs of pre-service education as well as the importance of continuing education and supervision that will allow teachers to develop and utilize their professional skills to deliver effective instruction in science.

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